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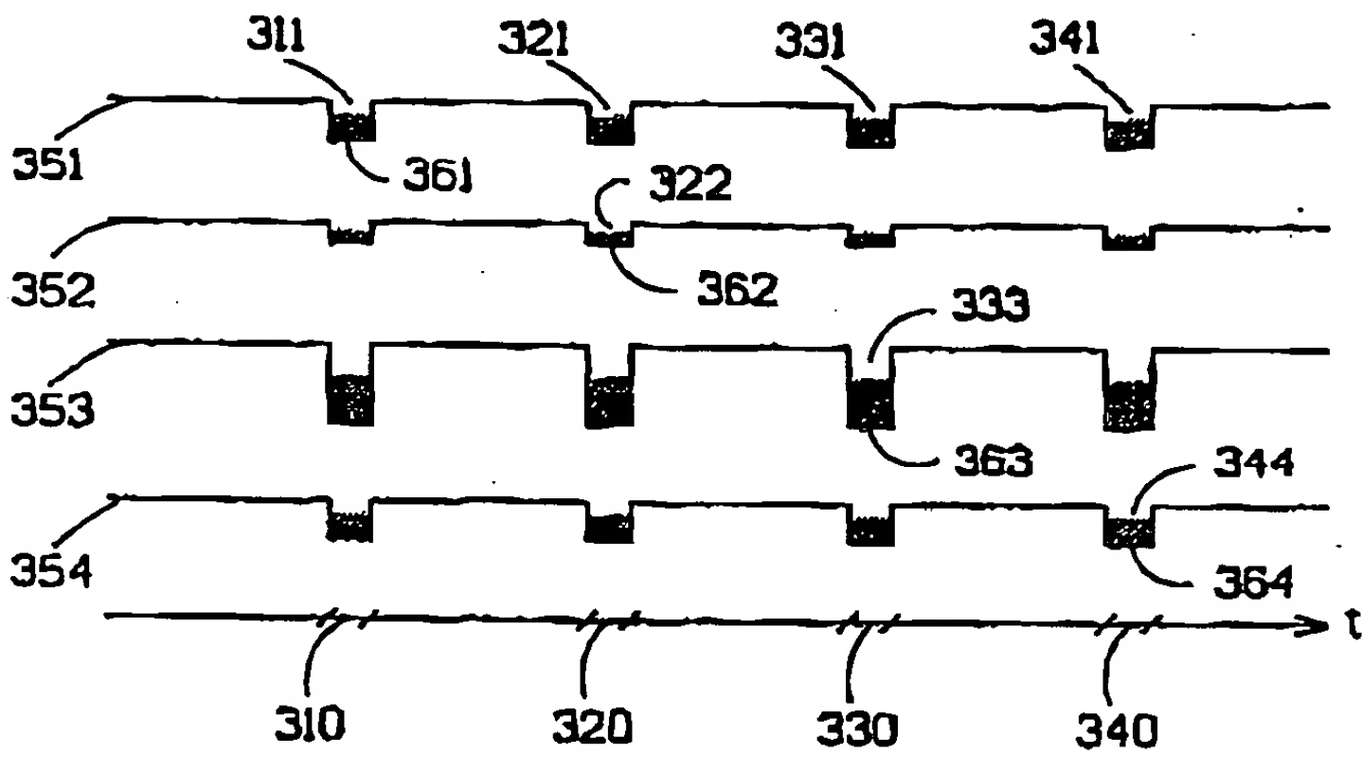

(57) Abstract

A method and a device for test receiving alternative frequencies without interrupting the reception of DAB frames from the current reception frequency in a DAB receiver. A DAB frame comprises a null symbol which is used to do a first very coarse synchronisation of the receiver to the transmitted signals. According to the invention, test receptions of alternative frequencies occur during the currently received programme's null symbols. By performing test receptions during the current programme's null symbols the current programme is not interrupted at all during the test receptions. A subsequently determined frequency changeover can thereafter, with a high probability, be performed without any noticeable interruption.

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METHOD AND DEVICE FOR CHANGE OF RECEPTION FREQUENCY IN A DIGITAL AUDIO BROADCASTING SYSTEM RECEIVER

FIELD OF THE INVENTION

The present invention relates generally to a method and a device for change of reception frequency in a radio-frequency receiver, especially mobile radiofrequency receivers, in the intersection area between radio broadcasting regions with different broadcasting frequencies, especially in a radiofrequency receiver for a digital audio broadcasting system (DAB).

BACKGROUND TO THE INVENTION

A conventional mobile FM-radio receiver, such as a car radio, has to change reception frequency when moving from one broadcasting area/region covered by one transmitter to another broadcasting area/region covered by another transmitter. Adjacent FM-radio broadcasting transmitters cannot transmit with the same radiofrequency, because if they did, due to the analog modulation of the radiofrequency signals, cross interference between the adjacent transmitters would arise. Therefore adjacent/ different FM-radiobroadcasting transmitters, independently if they broadcast different information in the same area or the same information in adjacent areas, transmit with sufficiently different frequencies to avoid cross interference.

Frequencies are reused in broadcast areas that are sufficiently distant from each other so that cross interference does not occur. The FM-radio broadcasting

system uses a relatively small bandwidth for each channel, this facilitates frequency changeover when a shift from one broadcasting transmitter to another is desired due to, for example, a transfer from one transmitter's broadcasting area to another.

Probably one of the first solutions for relieving, for example, a car driver from the burden of changing reception frequency when traveling from one FM-radiobroadcasting area to another was to, when the field strength of the currently received signal had fallen below a preset value, let the radio receiver scan the frequency area closest to the reception frequency in order to find an alternative reception frequency. An improvement to this is to let the FM-radio receiver measure the field strengths of several alternative reception frequencies and then change over to the one with the highest field-strength. The car driver, in these examples, does not have to fiddle about with the radio reciever but the reception gets interrupted while the receiver scans and possibly measures the alternative frequencies.

Radio data system (RDS) is an enhancement of and implemented into many analog FM-radio broadcasting systems. RDS provides certain improvements to the functioning of frequency changeover. An RDS FM-radio receiver will usually have the capability to store a list, received via RDS, of alternative frequencies for the current programme, for example a regionally or nationally broadcasted programme. When the received audio level is low, an RDS FM-radio will quickly change reception frequency to one of the alternative frequencies to thereby measure the alternative frequency's field strength in a test reception. The listener will usually not notice these short test receptions of alternative frequencies as the system utilizes short silences in speech or music in the current

programme. The audio output is preferably muted during the test receptions as well. The results of the test receptions will usually be the inputs to some sort of decision unit which will decide when and to which alternative frequency a frequency changeover should take place. This will probably, most of the time, be an unnoticeable function for the user, as it should be, letting, for example, a driver devote his full concentration on driving.

To avoid some disadvantages that are inherent in an analog FM-radio broadcasting system a new digital radio broadcasting system, digital audio broadcasting (DAB), has emerged. DAB which uses coded orthogonal frequency division multiplexing (COFDM) modulation was primarily intended as a single frequency network (SFN) to thereby broadcast four to twenty different nationally or regionally distributed audio programmes, the number depending on audio quality, i.e. coded audio rate, and the desired protection level. In a single frequency network a DAB-radio receiver does not have to switch reception frequency when travelling between regions covered by different transmitters as they all transmit the same programmes/ information with the same frequency.

However, there probably will evolve a demand from local and community broadcasters to use the DAB system to thereby take advantage of the benefits that the DAB system provides over the older analog FM-radio system. These regional, local, and/or community DAB broadcasting regions will require a frequency distribution plan equivalent to that of the FM-broadcasting system. As the DAB system will allow four to twenty different programmes to be broadcast simultaneously and as probaly not all of these are required for local/ community broadcasters then one or more of these can be of a regional or national type. Even though the DAB

broadcasting system was not envisaged as anything else than an SFN, there has now, in a DAB system, arisen a need to be able to switch/changeover reception frequency without the involvement of the listener or actually disturbing the listener with an unwarrented silence.

As mentioned, the DAB system uses a COFDM modulation technique which provides a robust method of information transfer. But due to, for exampel, the interleaving and the decoding of the digital data stream, the digital data stream cannot be interrupted for a test reception of an alternative frequency to thereby implement an unnoticeable method of test receiving alternative frequencies equivalent to that of the RDS system mentioned above. DAB is spectrally very robust but temporally somewhat more fragile. DAB can loose some sub carriers, due to, for example, fading, some of the time but the data stream cannot be cut off for a time period necessary for a test reception of alternative frequencies.

To somewhat provide a solution to the problem of finding alternative frequencies for a current programme, the DAB system broadcasts alternative frequencies of the current programme so that a list of these can be maintained in the receiver in a manner comparable to that of the RDS system. The DAB receiver will, in accordance to the methods used previously in other systems, when the field strength of the received programme falls below a preset threshold or according to a tendency of the field strength, interrupt the reception of the programme and perform test receptions of the alternative frequencies in the list. The reception of the current programme is unfortunately interrupted for a time interval, which can be considered annoying. As an alternative, a DAB receiver can arbitrarily choose one of the alternative frequencies on the list and perform a frequency change inbetween two information frames. If such

a method is used then there exists a certain probability that the correct frequency is selected and that therefore no interruption will occur. On the other hand there is also a high probability that the frequency is incorrect and that several frequency changes has to be performed with a considerable interruption of the programme as a result of this.

SUMMARY OF THE INVENTION

An object of the invention is to define a method and a device for providing an automatic change of reception frequency in a DAB receiver, especially a mobile DAB receiver, without any interruption or only a practically unnoticeable interruption of the current programme.

Another object of the invention is to define a method and a device which are able to deliver a preferable alternative frequency in a DAB receiver for a current programme without interrupting the current programme.

A further object of the invention is to define a method and a device which are able to test receive an alternative reception frequency for evaluation purposes in a DAB receiver without interrupting the currently received programme/ information.

A still further object of the invention is to define a method and a device which are able perform an automatic change of reception frequency to one alternative frequency which is preferable over the current frequency, when a DAB receiver is in the intersection between two or more broadcasting areas with different transmitter frequencies which transmit at least one common programme or programme

type, without interrupting the received programme for test receptions of the alternative frequencies.

The above-mentioned objects are achieved in accordance with the invention by a method of test receiving alternative frequencies without interrupting the reception of the information carrying part of DAB frames from the current reception frequency in a DAB receiver. A receiver for carrying out the method according to the invention is also provided. A DAB frame comprises a null symbol which is used to do a first very coarse synchronisation of the receiver to the transmitted signals. After the initial synchronisation, the phase reference symbols, which are the subsequent symbols, synchronises the receiver with the transmitter. Initially the null symbol was intended to be completely empty, but in later revisions of the DAB standard, the null symbol comprises a specially coded transmitter identification information (TII). The TII is transmitted with a lower average power value during the symbol time to thereby still allow the null symbol to correctly function as a null symbol. According to the invention, test receptions of alternative frequencies are performed during the currently received programme's null symbols. A test reception performs a switch of the reception frequency from the currently received frequency to a frequency which is to be tested, and at the end of the test reception the reception frequency is switched back to the originally received frequency, i.e. the currently received frequency, unless a permanent switch of frequency is determined. A switch of reception frequency has to be performed during test receptions because according to the invention only one reception chain is used. According to the invention a test reception is only performed as not to interfere with the reception of the currently received programme, i.e. the information carrying parts of the DAB frame. If the null symbols of the alternative frequencies

occur at the same time as the current programme's null symbols the received TII of the alternative frequencies are used for evaluation purposes. By performing test receptions during the current programme's null symbols the current programme is not interrupted at all during the test receptions. A subsequently determined frequency changeover can thereafter, with a high probability, be performed without any noticeable interruption.

The aforementioned objects are also achieved according to the invention by a method for providing an automatic change of reception frequency in a digital audio broadcasting (DAB) system receiver between a currently received frequency and a, from a field strength point of view, preferable alternative reception frequency. The receiver only having one reception chain for DAB. The preferable alternative reception frequency might well be the currently received frequency. The currently received frequency is in a digital audio broadcasting system format comprising transmission frames where each transmission frame comprises multicarrier symbols and a coarse synchronisation symbol in the form of a null symbol. The currently received frequency is meant to denote the frequency that is received when the procedure of the method according to the invention commences. The method comprises a number of steps in a digital audio broadcasting receiver. First of all, a list of alternative frequencies is determined. The list might consist of only one alternative frequency or a plurality. The currently received frequency can preferably be included in the list. The list might be assembled from all or selected frequencies from those included in the information received by the currently received DAB transmission, preprogrammed frequencies, one or more random frequencies generated, for example, from a random generator, all or selected frequencies in the neighbourhood of the currently received frequency, or all or selected frequencies in the

frequency range of the digital audio broadcasting receiver or a combination of any of these possibilities. When it has been determined what frequencies should be test received then test receptions of the alternative frequencies on the determined list are systematically performed. The test receptions are mainly performed during the null symbols of the digital audio broadcasting frames of the currently received frequency. Preferably the test receptions are only performed during the null symbols of the currently received frequency or alternatively the test receptions are performed during the null symbols and at least during part of at least one phase reference symbol of the currently received frequency. After or interleaved with the test receptions of the alternative frequencies the test receptions of the alternative frequencies on the determined list are evaluated. In one preferred method the alternative frequencies on the determined list are systematically test received at least once each before the evaluation of the test receptions. In another preferred method the alternative frequencies on the determined list are systematically test received only once each before the evaluation of the test receptions. In yet another preferred embodiment the alternative frequencies on the determined list are systematically test received at least twice each before the evaluation of the test receptions and the evaluation of the test receptions is based on calculated tendency of the field strength of each alternative frequency on the determined list. Based on the evaluation of the test receptions of the alternative frequencies on the determined list, which one of the alternative frequencies or the currently received frequency is preferable from a field strength point of view is determined. The currently received frequency might, as was mentioned previously, be included in the list of determined alternative frequencies, but it is important not to forget it as it might be the best one for the time being. When it

has been determined which frequency is preferable the reception frequency is changed to the determined preferable reception frequency. Preferably the changing of reception frequency to the determined preferable reception frequency is performed/ executed inbetween two digital audio broadcasting frames of the currently received frequency. The determined preferable reception frequency might be the currently received frequency and in such a case the change of frequency is not to another frequency. The method according to the invention thereby enables an automatic change of reception frequency in a digital audio broadcasting receiver without any interruption or only a practically unnoticeable interruption of the current programme. At least one alternative frequency on the determined list can advantageously be a digital audio broadcasting system transmission. The transmission frames of the different digital audio broadcasting systems preferably comprise transmitter identification information during the null symbols and which frames are preferably in principle synchronised. At least one of the alternative frequencies on the determined list can advantageously be of the FM or AM radio broadcasting type and in a preferred embodiment the evaluation of the test receptions further comprises the step of determining what type of broadcasting system each alternative frequency broadcasts.

The aforementioned objects are also achieved by a method for test receiving alternative reception frequencies in a digital audio broadcasting (DAB) system receiver for the purpose of being able to determine a, from a field strength point of view, preferable alternative reception frequency. The receiver tuned to a currently received frequency in a digital audio broadcasting system format receives a current programme/ information. The DAB format of the currently received frequency comprises transmission frames. Each transmission frame comprises multicarrier symbols and a

coarse synchronisation symbol in the form of a null symbol. The currently received frequency is meant to denote the frequency that is received when the procedure of the method according to the invention commences. The method comprises a number of steps in a digital audio broadcasting receiver. First of all, a list of alternative frequencies is determined. The list might consist of only one alternative frequency or a plurality. The currently received frequency can preferably be included in the list. The list might be assembled from all or selected frequencies from those included in the information received by the currently received DAB transmission, preprogrammed frequencies, one or more random frequencies generated, for example, from a random generator, all or selected frequencies in the neighbourhood of the currently received frequency, or all or selected frequencies in the frequency range of the digital audio broadcasting receiver or a combination of any of these possibilities. When it has been determined what frequencies should be test received then test receptions of the alternative frequencies on the determined list are systematically performed. The test receptions are mainly performed during the null symbols of the digital audio broadcasting frames of the currently received frequency. Preferably the test receptions are only performed during the null symbols of the currently received frequency or alternatively the test receptions are performed during the null symbols and at least during part of at least one phase reference symbol of the currently received frequency. After or interleaved with the test receptions of the alternative frequencies the test receptions of the alternative frequencies on the determined list are evaluated. In one preferred method the alternative frequencies on the determined list are systematically test received at least once each before the evaluation of the test receptions. In another preferred method the alternative frequencies on the determined list are systematically test received only once

each before the evaluation of the test receptions. In yet another preferred embodiment the alternative frequencies on the determined list are systematically test received at least twice each before the evaluation of the test receptions and the evaluation of the test receptions is based on calculated tendency of the field strength of each alternative frequency on the determined list. Based on the evaluation of the test receptions of the alternative frequencies on the determined list, which one of the alternative frequencies or the currently received frequency is preferable from a field strength point of view is determined. The currently received frequency might, as was mentioned previously, be included in the list of determined alternative frequencies, but it is important not to forget it as it might be the best one for the time being. The method according to the invention thereby enables the delivery of a preferable alternative frequency in a digital audio broadcasting receiver for a current programme/ information without interrupting the current programme/ information. At least one alternative frequency on the determined list can advantageously be a digital audio broadcasting system transmission. The transmission frames of the different digital audio broadcasting systems preferably comprise transmitter identification information during the null symbols and which frames are preferably in principle synchronised. At least one of the alternative frequencies on the determined list can advantageously be of the FM or AM radio broadcasting type and in a preferred embodiment the evaluation of the test receptions further comprises the step of determining what type of broadcasting system each alternative frequency broadcasts.

The aforementioned objects are also achieved by a method for test receiving alternative reception frequencies in a digital audio broadcasting system receiver for the purpose of being able to evaluate alternative reception

frequencies. The receiver tuned to a currently received frequency in a digital audio broadcasting system format receives a current programme/ information. The DAB format of the currently received frequency comprises transmission frames. Each transmission frame comprises multicarrier symbols and a coarse synchronisation symbol in the form of a null symbol. The currently received frequency is meant to denote the frequency that is received when the procedure of the method according to the invention commences. The method comprises a number of steps in a digital audio broadcasting receiver. First of all, a list of alternative frequencies is determined. The list might consist of only one alternative frequency or a plurality. The currently received frequency can preferably be included in the list. The list might be assembled from all or selected frequencies from those included in the information received by the currently received DAB transmission, preprogrammed frequencies, one or more random frequencies generated, for example, from a random generator, all or selected frequencies in the neighbourhood of the currently received frequency, or all or selected frequencies in the frequency range of the digital audio broadcasting receiver or a combination of any of these possibilities. The selection can, for example, be based on the geographical location of the corresponding receiver. When it has been determined what frequencies should be test received then test receptions of the alternative frequencies on the determined list are systematically performed. The test receptions are mainly performed during the null symbols of the digital audio broadcasting frames of the currently received frequency. Preferably the test receptions are only performed during the null symbols of the currently received frequency or alternatively the test receptions are performed during the null symbols and at least during part of at least one phase reference symbol of the currently received frequency. After or interleaved with the test

receptions of the alternative frequencies the test receptions of the alternative frequencies on the determined list are evaluated. In one preferred method the alternative frequencies on the determined list are systematically test received at least once each before the evaluation of the test receptions. In another preferred method the alternative frequencies on the determined list are systematically test received only once each before the evaluation of the test receptions. In yet another preferred embodiment the alternative frequencies on the determined list are systematically test received at least twice each before the evaluation of the test receptions and the evaluation of the test receptions is based on calculated tendency of the field strength of each alternative frequency on the determined list. The method according to the invention thereby enables an evaluation of alternative frequencies on a determined list without interrupting the currently received programme/information. At least one alternative frequency on the determined list can advantageously be a digital audio broadcasting system transmission. The transmission frames of the different digital audio broadcasting systems preferably comprise transmitter identification information during the null symbols and which frames are preferably in principle synchronised. At least one of the alternative frequencies on the determined list can advantageously be of the FM or AM radio broadcasting type and in a preferred embodiment the evaluation of the test receptions further comprises the step of determining what type of broadcasting system each alternative frequency broadcasts.

The aforementioned objects are also achieved by a method for test receiving an alternative reception frequency in a digital audio broadcasting system receiver for the purpose of being able to evaluate an alternative reception frequency. The receiver tuned to a currently received

frequency in a digital audio broadcasting system format receives a current programme/ information. The DAB format of the currently received frequency comprises transmission frames. Each transmission frame comprises multicarrier symbols and a coarse synchronisation symbol in the form of a null symbol. The currently received frequency is meant to denote the frequency that is received when the procedure of the method according to the invention commences. The method comprises a number of steps in a digital audio broadcasting receiver. First of all the test reception of the alternative frequency is performed. The test reception is mainly performed during a null symbol of a digital audio broadcasting frame of the currently received frequency. Preferably the test reception is only performed during a null symbol of the currently received frequency or alternatively the test reception is performed during a null symbol and at least during part of at least one phase reference symbol of the currently received frequency. After the test reception of the alternative frequency the test reception of the alternative frequency is evaluated. In one preferred method the alternative frequency is test received at least once before an evaluation of the test receptions. In another preferred method the alternative frequency is test received only once before the evaluation of the test reception. In yet another preferred method the alternative frequency is test received at least twice before an evaluation of the test receptions and the evaluation of the test receptions is based on a calculated tendency of the field strength of the alternative frequency. The method according to the invention thereby enables the an evaluation of an alternative frequency without interrupting the currently received programme/ information.

The aforementioned objects are achieved in accordance with the invention also by a device for test receiving

alternative reception frequencies in a digital audio broadcasting system receiver for the purpose of being able to evaluate alternative reception frequencies. The receiver tuned to a currently received frequency in a digital audio broadcasting system format receives a current programme/ information. The DAB format of the currently received frequency comprises transmission frames. Each transmission frame comprises multicarrier symbols and a coarse synchronisation symbol in the form of a null symbol. The currently received frequency is meant to denote the frequency that is received before the device commences to test receive alternative frequencies according to the invention. The device comprises means for determining a list of alternative frequencies. The list might consist of only one alternative frequency or a plurality. The currently received frequency can advantageously be included in the list. The list might be assembled from all or only selected frequencies from those included in the information received by the currently received DAB transmission, preprogrammed frequencies, one or more random frequencies generated, for example, from a random generator, all or only selected frequencies in the neighbourhood of the currently received frequency, or all or only selected frequencies in the frequency range of the digital audio broadcasting receiver or a combination of any of these possibilities. The device further comprises means for systematically performing test receptions of the alternative frequencies on the determined list. The test receptions are mainly performed during the null symbols of the digital audio broadcasting frames of the currently received frequency. The device also comprises means for evaluating the test receptions of the alternative frequencies on the determined list. The evaluation can be performed either after or interleaved with the the test receptions of the alternative frequencies. Thereby the device is able to perform an evaluation of alternative

frequencies on a determined list without interrupting the currently received programme/information. In some embodiments of the invention the device preferably further comprises means for determining which one of the alternative frequencies or the currently received frequency is preferable from a field strength point of view. The determination is based on the evaluation of the test receptions of the alternative frequencies on the determined list. The device is thereby enabled to deliver a preferable alternative frequency for a current programme/ information in a digital audio broadcasting receiver without interrupting the current programme/ information. In other embodiments of the invention the device preferably further comprises means for changing the reception frequency to the determined preferable reception frequency. Preferably the means for changing the reception frequency to the determined preferable reception frequency executes a change of frequency inbetween two digital audio broadcasting frames of the currently received frequency. The device is thereby able to automatically change the reception frequency in a digital audio broadcasting receiver without any interruption or only a practically unnoticeable interruption of the current programme. In some embodiments the means for systematically performing the test receptions only performs test receptions during the null symbols of the currently received frequency. In other embodiments the means for systematically performing the test receptions performs test receptions during the null symbols and at least during part of at least one phase reference symbol of the currently received frequency. In some embodiments the means for systematically performing test receptions systematically performs test receptions of the alternative frequencies at least once each before the means for evaluating the test receptions evaluates the test receptions. In other embodiments the means for systematically performing test receptions systematically

performs test receptions of the alternative frequencies only once each before the means for evaluating the test receptions evaluates the test receptions. In alternative embodiments the means for systematically performing test receptions systematically performs test receptions of the alternative frequencies at least twice each before the means for evaluating the test receptions evaluates the test receptions and that the means for evaluating the test receptions bases its evaluation on a calculated tendency of the field strength of each alternative frequency on the determined list. Preferably at least one alternative frequency on the determined list is a digital audio broadcasting system transmission and where the transmission frames of the different digital audio broadcasting systems comprises transmitter identification information during the null symbols which transmitter identification information is used by the means for evaluating the test receptions. In some circumstances at least one of the alternative frequencies on the determined list is of the FM or AM radio broadcasting type and that the means for evaluating the test receptions further determines what type of broadcasting system each alternative frequency broadcasts.

By providing a device and a method for test receiving alternative frequencies without interrupting the current programme, a plurality of advantages over prior art systems are obtained. Depending on how the frames are synchronised between the current reception frequency and an alternative frequency to which a change is to be performed, a more or less unnoticeable change can be executed. Under favourable conditions even a data transfer can be changed from one reception frequency to another without any loss of information. The device and method according to the invention will work just as well in a mobile receiver as in a stationary receiver. A stationary receiver might be located in an area which is an intersection of two or more

broadcasting areas with different transmitter frequencies in such a way that under certain conditions, weather conditions for example, one reception frequency is better than the other(s), and under different conditions another reception frequency is superior. The invention can also advantageously be utilised in a single frequency network where a full coverage DAB network is not yet achieved and where analog FM or AM broadcasting is utilised to complement the DAB network and thereby provide complete coverage for regional and/or national programmes. The difference being that test receptions are performed on alternative FM or AM frequencies instead of on DAB frames and that the evaluation of the test receptions are adapted according to the type of test reception performed.

DESCRIPTION OF THE FIGURES

The invention will now be described in more detail for explanatory, and in no sense limiting, purposes, with reference to the following figures, in which

Fig. 1 shows a block diagram of one DAB frame,

Fig. 2 shows a frequency coverage map,

Fig. 3 temporally shows null symbols of several different transmitting frequencies,

Fig. 4 shows a block diagram of a receiver according to the invention, and

Fig. 5 shows a flow chart of how the reception frequency in a receiver is changed according to one method of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

In order to clarify the system according to the invention, some examples of its use will now be described in connection with Figures 1 to 5.

Figure 1 shows a block diagram of one DAB frame. DAB frames are sent in succession. A DAB frame mainly comprises a synchronisation channel 101, 102, a fast information channel (FIC) 103, and a main service channel (MSC) 104. The synchronisation channel comprises a null symbol 101 and at least one phase reference symbol 102. The fast information channel (FIC) 103 is, for example, used for multiplex configuration information (MCI) and service information (SI). The main service channel 104 carries the desired useful information which can be a number of coded audio programmes/channels, one or more digital information transfers, or a combination of these. Usually more than one programme/channel or information transfer is coded into the main service channel.

A DAB frame is configured to provide a robust way of transferring information, i.e. packets of digital information, from a transmitter to a receiver without any feedback through, for example, a back channel. In the transmitter a DAB frame is assembled in the following manner; Packets of digital information are coded, error protected, and then time interleaved. These are thereafter multiplexed into the main service channel 104 according to a predetermined, but changeable, service configuration. The multiplexer output is frequency interleaved and combined with multiplex control and service information which travel in the fast information channel 103 in order to avoid the time interleaving process. Finally, very rugged synchronisation symbols 102 are added before applying orthogonal frequency division multiplexing (OFDM)

and differential quadrature phase-shift keying (QPSK) modulation onto a a large number of carriers to form the DAB signal.

Due to, among other things, the interleaving, not only within a single frame but also between different frames, the fast information channel 103 and the main service channel 104 cannot be interrupted for any substantial length of time without causing a substantial interruption of the received programme/information before the interleaving is complete again.

As mentioned previously, the null symbol 101 is used for coarse synchronisation and was originally intended to be completely empty, as the name implies. Later revisions of the DAB standard has introduced the possibility to use the null symbol 101 for transmitter identification. Transmitter identification is accomplished by transmitting a TII specific for the transmitter in question during the null symbol 101. This means that in an SFN the only deviating information transmitted by the transmitters is the TII during the null symbol and therefore the TII is coded in a special way and transmitted at a low power level to thereby avoid any interference problems and to enable the null symbol 101 to still function as a null symbol. According to the invention test receptions can be performed during the null symbol 101 and possibly during part of the synchronisation symbol 102 without interfering with the currently received programme and its necessary information carrying parts 103, 104. Test receptions of other frequencies can only be performed when the current programme is not disturbed since only one reception chain necessary and used according to the invention.

Figure 2 shows a frequency coverage map over four different broadcasting regions 211, 212, 213, 214, each region broad-

casting with a different frequency. Each broadcasting region 211, 212, 213, 214, has at least one transmitter 221, 231, 222, 232, 242, 223, 224. A first broadcasting region 211 comprises two transmitters 221, 231, to be able to cover the whole first region 211. The two transmitters 221, 231, of the first region 211 transmit at the same frequency and thereby takes advantage of the DAB system. A second broadcasting region 212 comprises three transmitters 222, 232, 242, to cover the whole second region 212. The number of necessary transmitters can, for example, depend on the geography of the region or transmitter output power level. The first and second regions 211, 212, are single frequency networks on a small scale.

Each one of the third and fourth broadcasting regions 213, 214, comprises a single respective transmitter 223, 224. These broadcasting regions 213, 214 can be of the DAB, FM, or AM type. The invention is not restricted to what type of broadcasting system a mobile receiver enters or a stationary receiver is in the vicinity of, but only that the currently received programme is transmitted from a DAB system since the invention deals with performing test receptions of alternative frequencies without interruption of the received DAB frames. It will be assumed in the following that all of the broadcasting regions 211, 212, 213, 214, are of the DAB type. Further it will be assumed that at least two of the broadcasting regions 211, 213, (the first and third 211, 213) broadcast at least one common programme/ information channel, the programme being the one that our mobile receiver 290 is receiving when travelling along a road 200 that goes through the first and third broadcasting regions 211, 213, in our example.

If the same programme is not available, a receiver would preferably change to an alternative frequency that

transmits the same type of programme that is currently received. In these circumstances it would be preferable if the change to an alternative frequency is a bit more reluctant, i.e. the current frequency and therefore current programme would be allowed to degrade a bit more before a change is performed than when the same programme is available and a change back and forth can be performed without, for example, a listener noticing these changes. The DAB standard has provisions for not only broadcasting alternative frequencies that transmit the same programme to the receiver, but also alternative frequencies that transmit the same type of programme, i.e. news, pop music, jazz, sport etc.

Test receptions of alternative frequencies is preferably done continuously, but change to an alternative frequency will usually only be close at hand when a receiver is located in a region/intersection 219 between two or more broadcasting regions 211, 213, as is illustrated in figure 2. According to the invention, test receptions of alternative frequencies are performed during the null symbols of the currently received DAB frames. Figure 3 temporally illustrates null symbols of several different transmitting frequencies 351, 352, 353, 354, where the top one 351 is assumed to be the currently received DAB frequency 351 with its DAB frames and corresponding null symbols 311, 321, 331, 341 occuring during respective time periods 310, 320, 330, 340. The other three frequencies 352, 353, 354, can, for example, correspond to the respective broadcasting regions 212, 213, 214, of figure 2, which have been broadcasted as alternative frequencies. They can be alternative frequencies if they, for example, transmit the same programme/information, the same type of programme, or just be something that broadcasts something.

Most probably, the DAB frames transmitted by different transmitters with different frequencies 351, 352, 353, 354, will be sufficiently synchronised so that the null symbols 321, 322, of the different respective DAB frames occur at substantially the same time 320. Irrespectively if the frames are synchronised or not, the time periods 310, 320, 330, 340 are when the null symbols 311, 321, 331, 341 of the currently received frequency 351 occur, i.e. when the test receptions of the alternative frequencies 352, 353, 354, occur.

If, for example, according to figure 2, a mobile receiver 290 travels along a road/path 200 through a first broadcasting region 211 towards a third broadcasting region 213 and currently is located in a region 219 which is an intersection of the first 211 and third 213 regions, then the currently received frequency 351 is assumed to be that of the first region 211. According to the invention, test receptions of alternative frequencies can either be performed continuously or only when the reception level of the currently received frequency starts to deteriorate. In the example, test receptions will preferably be performed at least when the mobile receiver 290 is on its way to enter a new broadcasting region 213.

With reference to figure 3, when a first null symbol 311 for the current frequency 351 occurs at a first time period 310, the receiver could perform an internal test on its own TII 361 to thereby realize that test receptions of the alternative frequencies 352, 353, 354, are necessary. Therefore, during a second null symbol 321 of the currently received frequency and thus during a second time period 320, a test reception of the second frequency 352 is performed. During this test reception, most probably, a null symbol 322 and its corresponding TII 362 are received and evaluated. Correspondingly, test receptions of the

third 353 and fourth 354 frequencies are performed during the current 351 frequency's third 331 and fourth 341 null symbols which occur at the third 330 and fourth 340 time periods respectively. During the third 330 and fourth 340 time periods, if the third and fourth frequencies are somewhat in synchronisation with the currently 351 received frequency, their null symbols 333, 344 and their respective TII's 363, 364 will be received and evaluated.

This procedure can be repeated several times until the receiver determines that an alternative frequency will provide a superior reception quality compared to the currently received frequency, which is when a change of reception frequency is initiated. In the example, as illustrated by figures 2 and 3, a changeover to the third alternative frequency 353 broadcasted in the third region 213 is a probable outcome. As mentioned previously, the alternative frequencies are not necessarily DAB transmissions and even if they are, it is not necessary for the invention that they are synchronised. The receiver performs test receptions of alternative frequencies during the null symbols of the currently received DAB transmission and frequency. Independently of what is received during these test receptions of the alternative frequencies, an evaluation of the received signals is performed. A prediction as to the tendency, stronger and stronger or weaker and weaker, of the received signal can also possibly be done to support the determination as to what frequency a change should be executed to and also when this should happen. Depending on the specific embodiment of the invention, the evaluation may comprise a determination of what type of signals are received, i.e. DAB, FM, or AM, so that an evaluation may take into account not only the received signal strength but also the received signal strength in view of the type of received signals. The determination of what type of signals that are received can

be performed by using fast fourier transform (FFT) for a frequency analysis over time and/or an attempt at decoding the received signals.

Figure 4 shows a block diagram of a receiver according to the invention. The receiver will preferably either comprise an antenna 470 or means for connecting an external antenna. Signals picked up by the antenna 470 will preferably first of all be amplified in a preamplifier/ tuner 471 which preferably comprises mixing means for transposing the received signals to an intermediate frequency (IF). The heart of a DAB receiver will process its signals in a digital form and if a quadrature demodulator 472 is realised in digital form the quadrature demodulator 472 will have an analog to digital converter (A/D converter) at the input or if the quadrature demodulator 472 is realised in analog form then it will have an analog to digital converter on its output. The processing according to the invention is performed digitally by a digital signal processing means 473 preferably in conjunction with the ordinary digital signal processing that is required for extracting the received programme/information in a robust manner. Assuming that this is a DAB radio receiver, then the extracted programme, which is in a digital format, needs to be converted to analog signals in a digital to analog converter (D/A converter) 474. Unless very low levels of sound is adequate, then the analog signals needs to be amplified in an amplifier 475 before the analog signals are fed to a speaker 476, headphones, or the like.

The present invention can be put into apparatus-form either as pure hardware, as pure software or as a combination of hardware and software. If the method according to the invention is realised in the form of software, it can be completely independent or it can be one part of a larger

programme. The software can suitably be located in a general purpose computer or in a dedicated computer.

Fig. 5 shows a flow chart of how the reception frequency in a receiver is changed according to one method of the invention. In an optional field strength measuring step 580, the field strength of the currently received frequency is measured. Thereafter in an optional field strength test step 581, the measured field strength of the currently received frequency is either compared to a fixed threshold value or used in a field strength prediction computation with which a tendency is computed and thereafter compared with model tendencies. If the field strength is above the fixed threshold or does not show a weakening tendency, then the procedure returns to field strength measuring step 580. On the other hand, if the field strength is below a fixed threshold or shows a weakening tendency, then the procedure proceeds to null symbol step 582 which will be described in full below. These two optional steps 580, 581 are optional, the method according to the invention, as described below, can be performed continuously, initiated by another program, or initiated on demand by other methods/ devices than by the method which has been described in relation to the two optional steps 580, 581.

When it is determined that test receptions of alternative frequencies should be performed, for example according to the previously described optional steps 580, 581, then it is determined, in a null symbol step 582, when in time the null symbols appear. According to the invention, in order not to interrupt the reception of the currently received programme/ information, test receptions of alternative frequencies are performed during the null symbols of the currently received DAB frames. By using the null symbol the information transfer part of the DAB frame is not interrupted and only the TII of the currently received

frequency is lost for that frame. The TII is probably the only part of a DAB frame that will be the same when DAB frames are received from the same transmitter, the loss of the TII from a few frames will not affect the reception in any way. When the temporal location of the null symbols have been identified, then the reception frequency of the receiver is switched to an alternative frequency, during a null symbol and only during the null symbol, in an alternative frequency step 583. The alternative frequency that is switched to will preferably come from a list that is maintained by the receiver by means of information received from DAB. During the null symbol, signals are received from the alternative frequency and measured and analysed in a measuring step 584. Before the end of the null symbol the receiver switches reception frequency back to the currently received frequency in a switch-back step 585, for reception of the information carrying part of the frame.

When the receiver is once again receiving the currently received programme/ information, a more alternatives test step 586 tests if there are more alternative frequencies to perform a test reception on. If there are more alternative frequencies, then the procedure preferably continues, either with the null symbol step 582 or with the alternative frequency step 583 depending on the specific implementation. On the other hand, if there are no more alternative frequencies, then the procedure continues to a determination step 587. The determination step 587 analyses the measurements which were taken during the measurement step 585 on the alternative frequencies and preferably the field strength measurements taken on the currently received frequency and determines in view of all the measurements if a switch/ change of reception frequency should be done and if so to what alternative frequency. A change reception frequency test step 588 will direct the

procedure in the correct direction in view of the outcome of the determination step 587. If it is determined that the receiver should change reception frequency, then the procedure continues to a change reception frequency step 589. If, on the other hand, the circumstances are such that the currently received frequency is still that which is preferable, then the procedure continues either to step 580, step 582, or step 583, or to something completely different, all depending on the specific implementation of the invention.

As a summary, the invention can basically be described as a device and a method which provide means to enable a change of reception frequency without any or very little interruption to the received programme.

The invention is not limited to the embodiments described above but may be varied within the scope of the appended patent claims.

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FIG 1

101 null symbol
102 phase reference symbol
103 FIC fast information channel
104 MSC main service channel - audio programmes

FIG 2

200 road
211 frequency 1 coverage
212 frequency 2 coverage
213 frequency 3 coverage
214 frequency 4 coverage
219 overlap between 211 and 213
221 transmitter 1 frequency 1
222 transmitter 1 frequency 2
223 transmitter 1 frequency 3
224 transmitter 1 frequency 4
231 transmitter 2 frequency 1
232 transmitter 2 frequency 2
242 transmitter 3 frequency 2
290 receiver / mobile receiver / car

FIG 3

310 time 1
311 null symbol at time 1 for frequency 1
320 time 2
321 null symbol at time 2 for frequency 1
322 null symbol at time 2 for frequency 2
330 time 3
331 null symbol at time 3 for frequency 1
333 null symbol at time 3 for frequency 3

340 time 4
341 null symbol at time 4 for frequency 1
344 null symbol at time 4 for frequency 4
351 frequency 1
352 frequency 2
353 frequency 3
354 frequency 4
361 tii at time 1 frequency 1
362 tii at time 2 frequency 2
363 tii at time 3 frequency 3
364 tii at time 4 frequency 4

FIG 4

470 antenna
471 preamplifier
472 A/D converter
473 digital signal processing
474 D/A converter
475 amplifier
476 speaker

FIG 5

580 optional - field strength measuring step
581 optional - field strength test step
582 null symbol step
583 alternative frequency step
584 measurement step
585 switch back step
586 more alternative frequencies test step
587 determination step
588 change reception frequency test step
589 change reception frequency step!

CLAIMS

1. A method for providing an automatic change of reception frequency in a digital audio broadcasting system receiver between a currently received frequency in a digital audio broadcasting system format comprising transmission frames where each transmission frame comprises multicarrier symbols and a coarse synchronisation symbol in the form of a null symbol, to a, from a field strength point of view, preferable alternative reception frequency, characterized in that the method comprises the following steps in a digital audio broadcasting receiver:

- determining a list of alternative frequencies;
- systematically performing test receptions of the alternative frequencies on the determined list and performing the test receptions mainly during the null symbols of the digital audio broadcasting frames of the currently received frequency;
- evaluating the test receptions of the alternative frequencies on the determined list;
- based on the evaluation of the test receptions of the alternative frequencies on the determined list determining which one of the alternative frequencies or the currently received frequency is preferable from a field strength point of view;
- changing the reception frequency to the determined preferable reception frequency;

thereby enabling an automatic change of reception frequency in a digital audio broadcasting receiver without any interruption or only a practically unnoticeable interruption of the current programme.

2. The method according to claim 1, characterized in that the test receptions are only performed during the null symbols of the currently received frequency.

3. The method according to claim 1, characterized in that the test receptions are performed during the null symbols and at least during part of at least one phase reference symbol of the currently received frequency.

4. The method according to any one of claims 1 to 3, characterized in that the changing of reception frequency to the determined preferable reception frequency is performed inbetween two digital audio broadcasting frames of the currently received frequency.

5. The method according to any one of claims 1 to 4, characterized in that the alternative frequencies on the determined list are systematically test received at least once each before the evaluation of the test receptions.

6. The method according to any one of claims 1 to 4, characterized in that the alternative frequencies on the determined list are systematically test received only once each before the evaluation of the test receptions.

7. The method according to any one of claims 1 to 4, characterized in that the alternative frequencies on the determined list are systematically test received at least twice each before the evaluation of the test receptions and that the evaluation of the test receptions is based on calculated tendency of the field strength of each alternative frequency on the determined list.

8. The method according to any one of claims 1 to 7, characterized in that at least one alternative frequency on the determined list is a digital audio broadcasting system

transmission and where the transmission frames of the different digital audio broadcasting systems comprises transmitter identification information during the null symbols and which frames are in principle synchronised.

9. The method according to any one of claims 1 to 8, characterized in that at least one of the alternative frequencies on the determined list is of the FM or AM radio broadcasting type and that the evaluation of the test receptions further comprises the step of determining what type of broadcasting system each alternative frequency broadcasts.

10. A method for test receiving alternative reception frequencies in a digital audio broadcasting system receiver where a currently received frequency in a digital audio broadcasting system format comprises a current programme/ information and comprises transmission frames where each transmission frame comprises multicarrier symbols and a coarse synchronisation symbol in the form of a null symbol, for the purpose of being able to determine a from a field strength point of view preferable alternative reception frequency, characterized in that the method comprises the following steps in a digital audio broadcasting receiver:

- determining a list of alternative frequencies;
- systematically performing test receptions of the alternative frequencies on the determined list and performing the test receptions mainly during the null symbols of the digital audio broadcasting frames of the currently received frequency;
- evaluating the test receptions of the alternative frequencies on the determined list;
- based on the evaluation of the test receptions of the alternative frequencies on the determined list determining which one of the alternative frequencies

or the currently received frequency is preferable from a field strength point of view;

thereby enabling the delivery of a preferable alternative frequency in a digital audio broadcasting receiver for a current programme/information without interrupting the current programme/information.

11. The method according to claim 10, characterized in that the test receptions are only performed during the null symbols of the currently received frequency.

12. The method according to claim 10, characterized in that the test receptions are performed during the null symbols and at least during part of at least one phase reference symbol of the currently received frequency.

13. The method according to any one of claims 10 to 12, characterized in that the alternative frequencies on the determined list are systematically test received at least once each before the evaluation of the test receptions.

14. The method according to any one of claims 10 to 12, characterized in that the alternative frequencies on the determined list are systematically test received only once each before the evaluation of the test receptions.

15. The method according to any one of claims 10 to 12, characterized in that the alternative frequencies on the determined list are systematically test received at least twice each before the evaluation of the test receptions and that the evaluation of the test receptions is based on calculated tendency of the field strength of each alternative frequency on the determined list.

16. The method according to any one of claims 10 to 15, characterized in that at least one alternative frequency on

the determined list is a digital audio broadcasting system transmission and where the transmission frames of the different digital audio broadcasting systems comprises transmitter identification information during the null symbols and which frames are in principle synchronised.

17. The method according to any one of claims 10 to 16, **characterized in that** at least one of the alternative frequencies on the determined list is of the FM or AM radio broadcasting type and that the evaluation of the test receptions further comprises the step of determining what type of broadcasting system each alternative frequency broadcasts.

18. A method for test receiving alternative reception frequencies in a digital audio broadcasting system receiver where a currently received frequency in a digital audio broadcasting system format comprises a current programme/ information and comprises transmission frames where each transmission frame comprises multicarrier symbols and a coarse synchronisation symbol in the form of a null symbol, for the purpose of being able to evaluate alternative reception frequencies, **characterized** in that the method comprises the following steps in a digital audio broadcasting receiver:

- determining a list of alternative frequencies;
- systematically performing test receptions of the alternative frequencies on the determined list and performing the test receptions mainly during the null symbols of the digital audio broadcasting frames of the currently received frequency;
- evaluating the test receptions of the alternative frequencies on the determined list;

thereby enabling an evaluation of alternative frequencies on a determined list without interrupting the currently received programme/information.

19. The method according to claim 18, characterized in that the test receptions are only performed during the null symbols of the currently received frequency.

20. The method according to claim 18, characterized in that the test receptions are performed during the null symbols and at least during part of at least one phase reference symbol of the currently received frequency.

21. The method according to any one of claims 18 to 20, characterized in that the alternative frequencies on the determined list are systematically test received at least once each before the evaluation of the test receptions.

22. The method according to any one of claims 18 to 20, characterized in that the alternative frequencies on the determined list are systematically test received only once each before the evaluation of the test receptions.

23. The method according to any one of claims 18 to 20, characterized in that the alternative frequencies on the determined list are systematically test received at least twice each before the evaluation of the test receptions and that the evaluation of the test receptions is based on calculated tendency of the field strength of each alternative frequency on the determined list.

24. The method according to any one of claims 18 to 23, characterized in that at least one alternative frequency on the determined list is a digital audio broadcasting system transmission and where the transmission frames of the different digital audio broadcasting systems comprises transmitter identification information during the null symbols and which frames are in principle synchronised.

25. The method according to any one of claims 18 to 24, characterized in that at least one of the alternative frequencies on the determined list is of the FM or AM radio broadcasting type and that the evaluation of the test receptions further comprises the step of determining what type of broadcasting system each alternative frequency broadcasts.

26. A method for test receiving an alternative reception frequency in a digital audio broadcasting system receiver where a currently received frequency in a digital audio broadcasting system format comprises a current programme/ information and comprises transmission frames where each transmission frame comprises multicarrier symbols and a coarse synchronisation symbol in the form of a null symbol, for the purpose of being able to evaluate an alternative reception frequency, characterized in that the method comprises the following steps in a digital audio broadcasting receiver:

- performing a test reception of the alternative frequency mainly during a null symbol of a digital audio broadcasting frame of the currently received frequency;
- evaluating the test receptions of the alternative frequency;

thereby enabling an evaluation of an alternative frequency without interrupting the currently received programme/ information.

27. A device for test receiving alternative reception frequencies in a digital audio broadcasting system receiver where a currently received frequency (351) in a digital audio broadcasting system format comprises a current programme/ information and comprises transmission frames where each transmission frame comprises multicarrier symbols and a coarse synchronisation symbol in the form of

a null symbol (101), for the purpose of being able to evaluate alternative reception frequencies, characterized in that the device comprises:

- means (473) for determining a list of alternative frequencies;
- means (473) for systematically performing test receptions of the alternative frequencies on the determined list and performing the test receptions mainly during the null symbols of the digital audio broadcasting frames of the currently received frequency;
- means (473) for evaluating the test receptions of the alternative frequencies on the determined list;

thereby enabling an evaluation of alternative frequencies on a determined list without interrupting the currently received programme/information.

28. The device according to claim 27, characterized in that the device further comprises means for determining which one of the alternative frequencies or the currently received frequency is preferable from a field strength point of view, based on the evaluation of the test receptions of the alternative frequencies on the determined list, thereby enabling the delivery of a preferable alternative frequency in a digital audio broadcasting receiver for a current programme/information without interrupting the current programme/information.

29. The device according to claim 28, characterized in that the device further comprises means for changing the reception frequency to the determined preferable reception frequency, thereby enabling an automatic change of reception frequency in a digital audio broadcasting receiver without any interruption or only a practically unnoticeable interruption of the current programme.

30. The device according to claim 29, characterized in that the means for changing the reception frequency to the determined preferable reception frequency executes a change of frequency inbetween two digital audio broadcasting frames of the currently received frequency.

31. The device according to any one of claims 27 to 30, characterized in that the means for systematically performing the test receptions only performs test receptions during the null symbols of the currently received frequency.

32. The device according to any one of claims 27 to 30, characterized in that the means for systematically performing the test receptions performs test receptions during the null symbols and at least during part of at least one phase reference symbol of the currently received frequency.

33. The device according to any one of claims 27 to 32, characterized in that the means for systematically performing test receptions systematically performs test receptions of the alternative frequencies at least once each before the means for evaluating the test receptions evaluates the test receptions.

34. The device according to any one of claims 27 to 32, characterized in that the means for systematically performing test receptions systematically performs test receptions of the alternative frequencies only once each before the means for evaluating the test receptions evaluates the test receptions.

35. The device according to any one of claims 27 to 32, characterized in that the means for systematically performing test receptions systematically performs test

receptions of the alternative frequencies at least twice each before the means for evaluating the test receptions evaluates the test receptions and that the means for evaluating the test receptions bases its evaluation on a calculated tendency of the field strength of each alternative frequency on the determined list.

36. The device according to any one of claims 27 to 35, characterized in that at least one alternative frequency on the determined list is a digital audio broadcasting system transmission and where the transmission frames of the different digital audio broadcasting systems comprises transmitter identification information during the null symbols which transmitter identification information is used by the means for evaluating the test receptions.

37. The device according to any one of claims 27 to 36, characterized in that at least one of the alternative frequencies on the determined list is of the FM or AM radio broadcasting type and that the means for evaluating the test receptions further determines what type of broadcasting system each alternative frequency broadcasts.

1/3

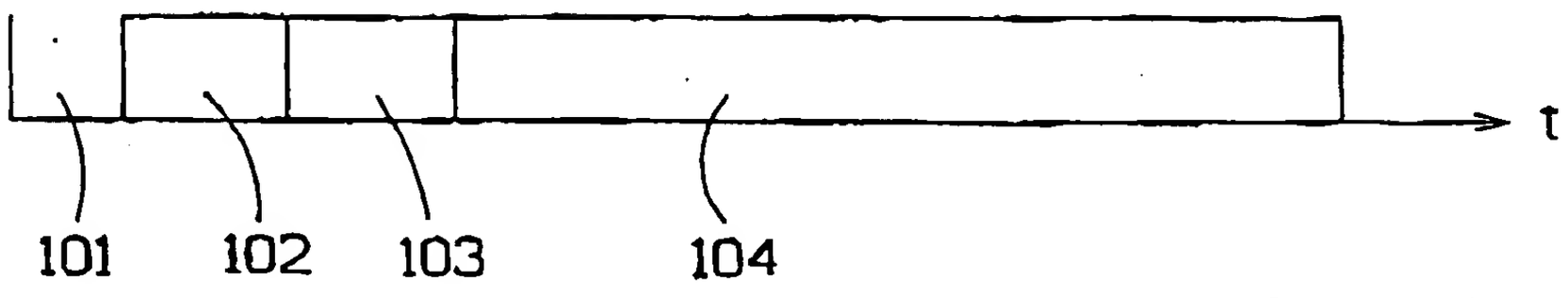

FIG.1

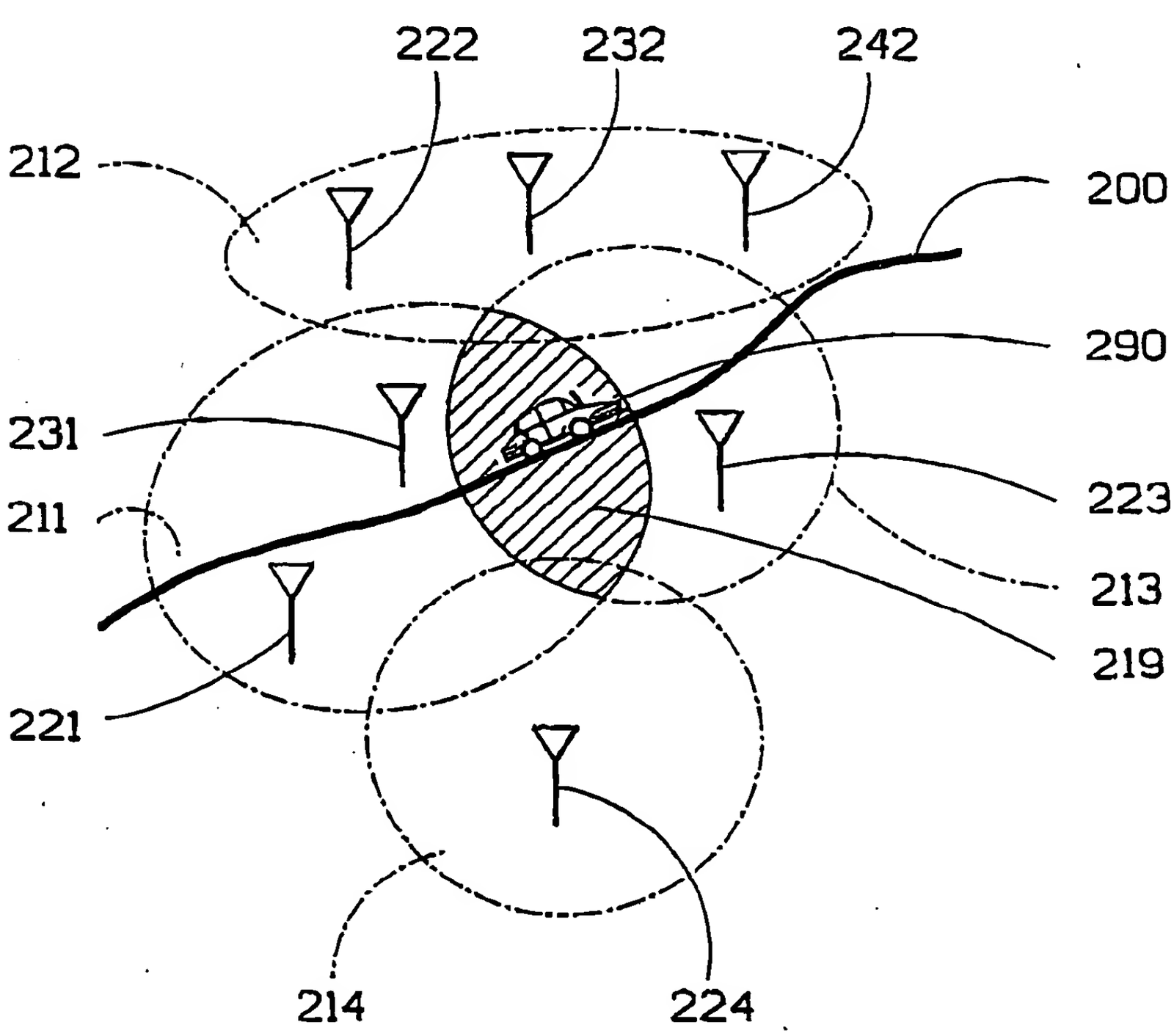

FIG.2

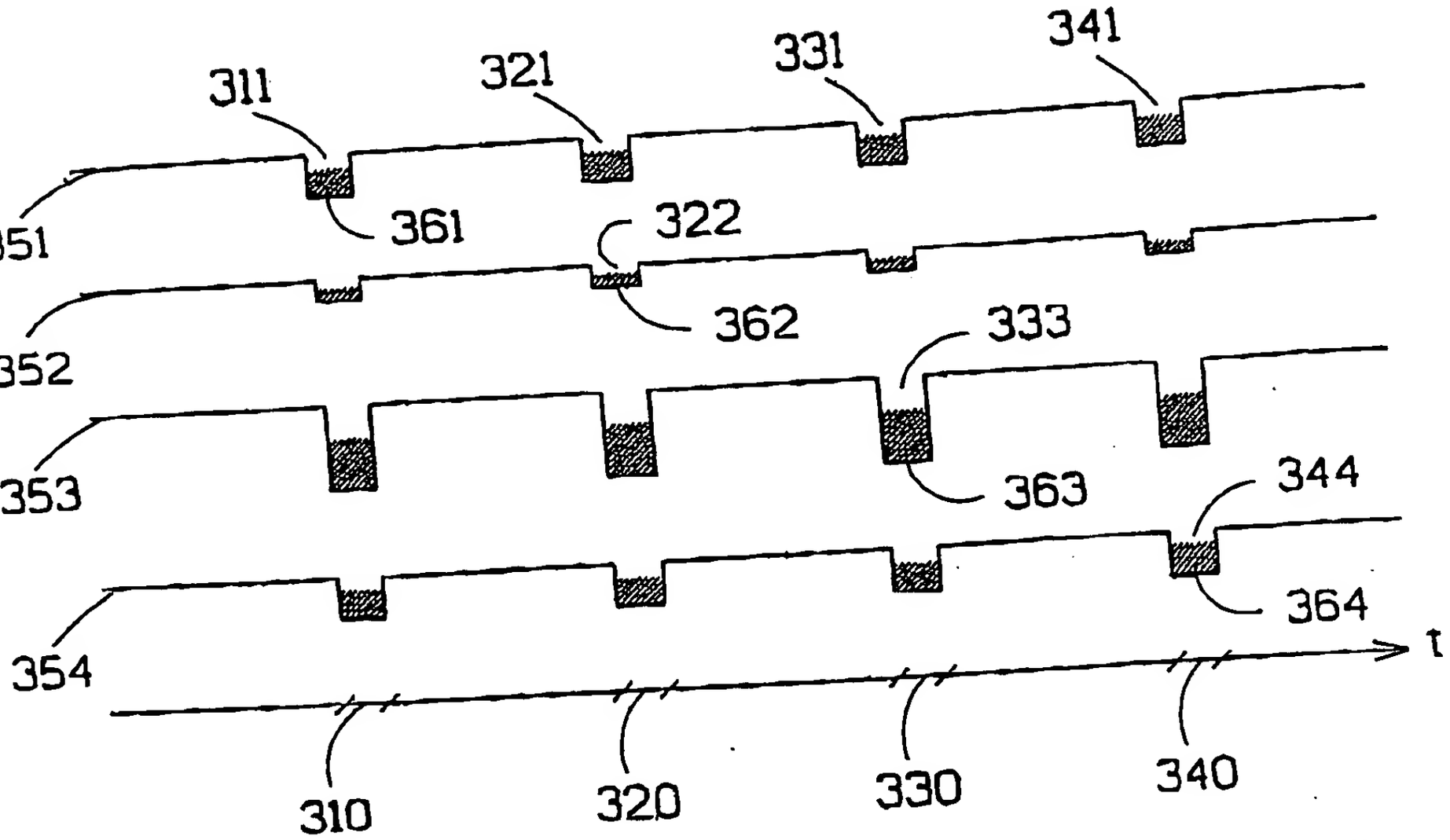

FIG.3

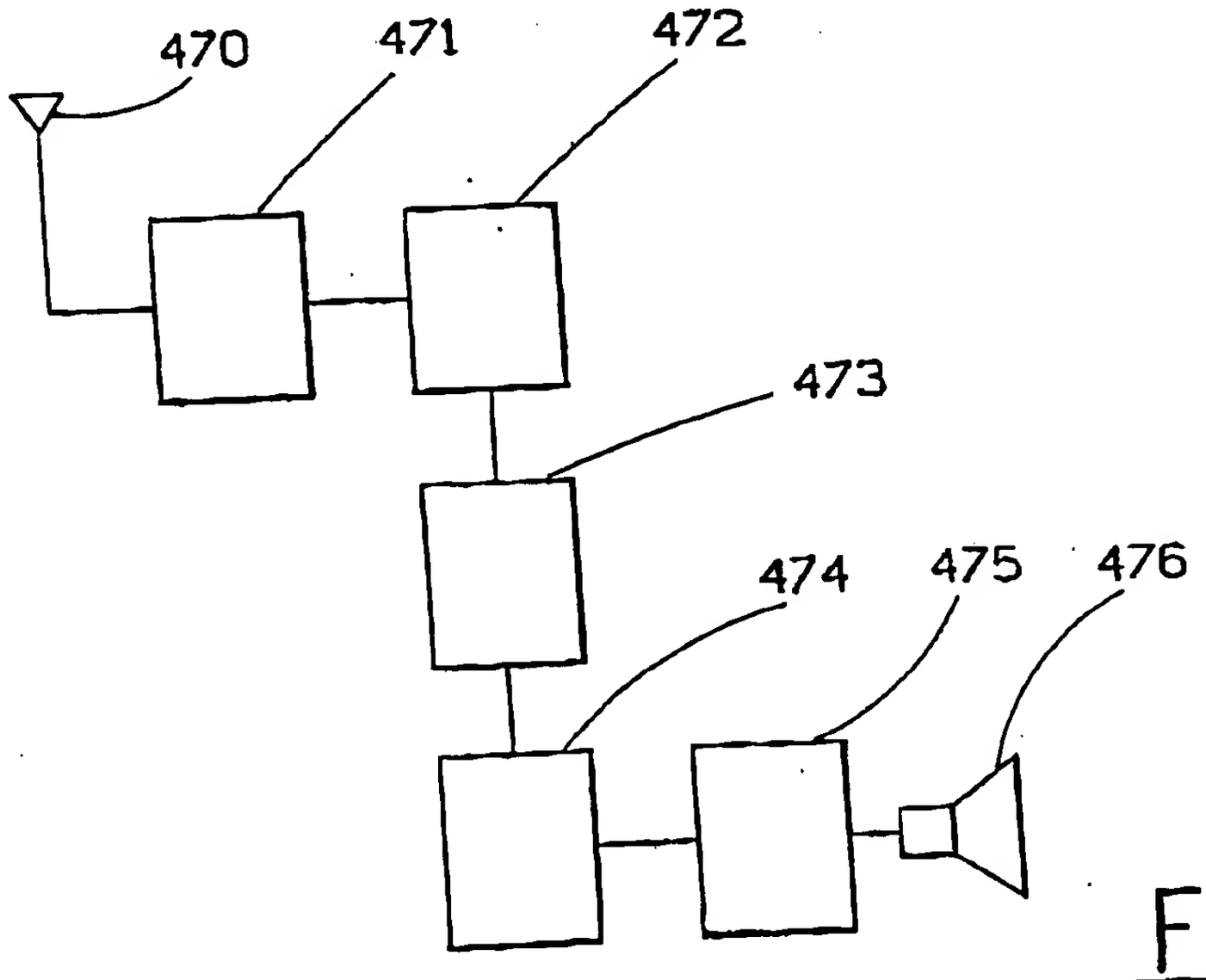

FIG.4

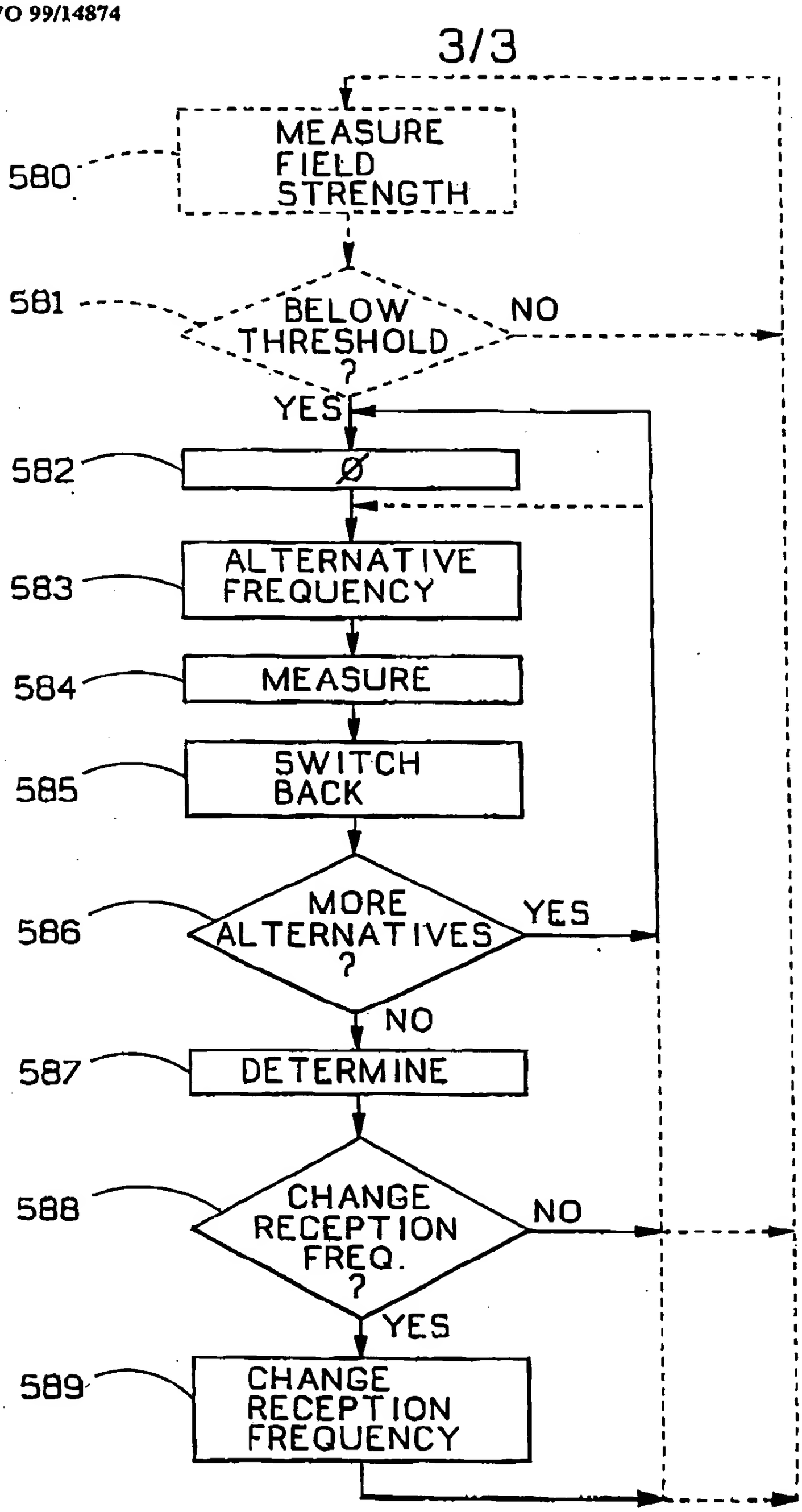

FIG.5